INTEROFFICE MEMO

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To: Doug Beckwith, Site Response Project Manager
From: Steve Hennes, Site Response Ecotoxicologist

Subject: Deer tissue samples from Pigs Eye Dump

I have reviewed the analytical chemistry data for the five white-tailed deer collected at the Pigs Eye Dump. The deer were collected during two sampling events by Minnesota DNR Conservation Officers using high-powered rifles. These deer had probably spent the majority of their time on the site during the preceding spring and summer months. Samples of liver, hind quarter muscle, and kidney fat were removed from each deer, wrapped in hexane-rinsed aluminum foil, placed in plastic bags and frozen for later delivery to the analytical lab. Results of the analyses for metals, PCBs and organochlorine pesticides are summarized in the attached table (Table 1).

Arsenic, chromium, mercury, nickel, selenium and silver were below detection limits and levels of concern in all five deer. However, copper and zinc were detected in muscle and liver of all five deer, and cadmium and lead were detected in one deer and three deer, respectively. The occurrence of copper and zinc is not surprising since these are trace elements required at minimum levels by deer for normal health. Zinc concentrations in liver (mean 35.2; range 33-39 ppm) showed little variation and were similar to mean liver concentrations from road-killed deer in Pennsylvania (39.4 ppm; Storm et al. 1994) and from deer collected on the Twin Cities Army Ammunition Plant (TCAAP) site in 1988-89 (range 16-41 ppm for four composite samples; FCC 1990), but higher than the mean concentration from deer in Illinois (20.3 ppm; Woolf et al. 1982). Zinc poisoning occurs in sheep at liver concentrations exceeding 135 ppm (Eisler 1993), well above concentrations in Pigs Eye deer. However, zinc accumulates primarily in muscle, and zinc levels were higher in muscle than liver in the three male Pigs Eye deer. The Pigs Eye deer muscle zinc concentrations (mean 43.4; range 35-55 ppm) were 2-3 times higher than muscle zinc concentrations found in the TCAAP deer (range 13-19 ppm for four composite samples), the only other muscle zinc concentration data for white-tailed deer that I could locate. No U.S. food residue guidelines could be found for zinc; however, a limit of 40 ppm zinc is allowed in Australian seafood (Table 2). Three of the five muscle samples exceeded 40 ppm, but since zinc is not particularly toxic to humans, these levels would probably not be hazardous for occasional consumption.

Liver copper concentrations (mean 10.0; range 3.7-23 ppm) were more variable than zinc and considerably lower than the mean values found in Pennsylvania (43.1 ppm; Storm et al. 1994) and Illinois deer (31.6 ppm; Woolf et al. 1982), possibly indicating a copper deficiency in the Pigs Eye deer. Elevated levels of zinc have been shown to limit copper metabolism and reduce copper tissue concentrations (Eisler 1993), so the high muscle zinc concentrations could provide an explanation for the apparently low copper levels in the Pigs Eye deer. Copper accumulates mainly in the liver, and copper levels were higher in liver than muscle in the Pigs Eye deer, opposite from the pattern observed for zinc. No other muscle copper concentration data could be found for white-tailed deer for comparison. As with zinc, no U.S. food residue guidelines or action levels could be found for copper, but the maximum permissible concentration of copper in animal products in Poland is 8 ppm (Table 2); all of the muscle samples were below 8 ppm copper.

Cadmium was detected in the liver and muscle of one deer only (Deer 1). This deer was a mature buck and the oldest deer collected, so residues may be age-related, since cadmium accumulates in tissues over time. The cadmium concentration of 0.7 ppm in liver exceeded all but one of 22 composites of livers from hunter-killed deer collected throughout Minnesota, and was higher than all three composites from the Twin Cities metropolitan area (max. 0.35 ppm; Ensor et al. 1993), as well as the four composites from TCAAP site deer (max. 0.5 ppm). The liver concentration also exceeded mean liver concentrations for white-tailed deer from Ohio (0.27 ppm; Sileo and Beyer 1985), Illinois (0.11 ppm; Woolf et al. 1992), and Pennsylvania (0.23 ppm; Storm et al. 1994). However, the Pigs Eye liver level is well below the tissue level of 13-15 ppm cadmium which probably represents a significant hazard to the deer (Eisler 1985). It is also below the proposed human health action standard (for consumption of liver) of 1.5 ppm cadmium in deer liver derived by Stansley et al. (1991), but exceeds the maximum allowable levels for liver of 0.5 ppm set by two other countries (Table 2). The muscle tissue concentration of 0.9 ppm in Deer 1 exceeded muscle cadmium concentrations in the TCAAP deer (below the detection limit of 0.5 ppm in all samples), Ontario deer (max. mean 0.2 ppm; Glooschenko et al. 1988) and deer from an unspecified U.S. location (range 0.0-0.7 ppm; Eisler 1985). It also exceeded maximum permissible levels for meat or foods other than liver (0.05-0.1 ppm) established by various countries (Table 2).

Lead was detected in liver and/or muscle of three deer. Lead concentrations in the livers of Deer 4 (0.45 ppm) and Deer 5 (0.3 ppm) exceeded all but two of 22 composites of livers (the rest ranged from <0.01 to 0.08 ppm) collected from hunter-killed deer throughout Minnesota and all 3 composites from Twin Cities metro area deer (Ensor et al. 1993), as well as all four composites from TCAAP deer livers (all < 0.1 ppm). However, the Pigs Eye concentrations were lower than the mean values for liver in Ohio deer (0.74 ppm; Sileo and Beyer 1985) and Illinois deer (1.3 ppm; Woolf et al. 1982), and well below concentrations likely to be related to toxic effects in deer (10-20 ppm in livestock; Eisler 1988). They were also below the suggested maximum allowable concentration of 0.8 ppm for human consumption of liver (Table 2). The concentration of 3.0 ppm in the muscle of Deer 1, the oldest deer collected, was quite high, though. Surprisingly, no lead was detected in the liver of this animal; lead normally accumulates in the liver. The muscle lead level (0.34 ppm) in Deer 4, the next oldest deer collected, also appears elevated. For comparison, the highest muscle concentration of lead found in four composite samples from deer collected on the TCAAP site was 0.2 ppm. I was unable to locate any other deer muscle lead residue data in the literature. Permissible lead concentrations in meat or other animal products range from 0.05 to 0.5 ppm in various countries (Table 2); the flesh of Deer 1 exceeded these values by several times, while Deer 4 exceeded the lower guideline values and approached the upper value.

PCBs and organochlorine pesticides were below detection limits in all fat samples, and estimated maximum concentrations in muscle, based on detection limits for fat samples and lipid content of muscle, were below the available FDA action levels for human consumption of animal products. Therefore deer do not appear to be accumulating hazardous levels of persistent organic compounds from the site.

Based on this very limited information, it does not appear that the majority of deer on the site are being exposed to levels of site-related contaminants that pose toxic hazards to the deer themselves, although possibly elevated zinc levels in muscle and low copper levels in liver may indicate exposure to zinc sufficient to affect the normal copper balance in these deer. Whether this is true or would be sufficient to have a detrimental effect on the health of the deer is unknown and would require further investigation. No PCBs or organochlorine pesticides were detected, and toxic metals were low or below detection limits in the youngest deer sampled. However, elevated concentrations of cadmium and lead in edible tissues of the oldest buck, and lead in the next younger buck, may indicate gradual accumulation of these metals from the site to levels that make it inadvisable to allow human consumption of older deer from the area. No hunting is currently allowed on the site, although evidence suggests that illegal hunting probably occurs. However, the high deer density has led to numerous road kills on nearby roads, and many of the carcasses have been provided to various organizations for food.

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Table 1	Chemical Concentrations in Pigs Eye Deer Tissues (mg/kg, wet wt.)														
	Deer 1			Deer 2			Deer 3			Deer 4			Deer 5		
	Male, > 2.5 yr			Female, < 1 yr			Male, 1.5 yr			Male, 2.5 yr			Female, 1.5 yr		
ANALYTE	Muscle	Liver	Fat	Muscle	Liver	Fat	Muscle	Liver	Fat	Muscle	Liver	Fat	Muscle	Liver	Fat
Metals															
Arsenic	<0.2	<0.2	NA	<0.2	<0.2	NA	<0.2	<0.2	NA	<0.2	<0.2	NA	<0.2	<0.2	NA
Cadmium	0.90	0.70	NA	<0.06	<0.06	NA	<0.06	<0.06	NA	<0.06	<0.06	NA	<0.06	<0.06	NA
Chromium	<0.17	<0.17	NA	<0.17	<0.17	NA	<0.17	<0.17	NA	<0.17	<0.17	NA	<0.17	<0.17	NA
Copper	5.0	7.0	NA	2.5	3.7	NA	2.4	8.6	NA	1.7	7.5	NA	1.9	23	NA
Lead	3.0	<0.25	NA	<0.25	<0.25	NA	<0.25	<0.25	NA	0.34	0.45	NA	<0.25	0.3	NA
Mercury	<0.011	<0.011	NA	<0.011	<0.011	NA	<0.011	<0.011	NA	<0.011	<0.011	NA	<0.011	<0.011	NA
Nickel	<0.23	<0.23	NA	<0.23	<0.23	NA	<0.23	<0.23	NA	<0.23	<0.23	NA	<0.23	<0.23	NA
Selenium	<0.5	<0.5	NA	<0.5	<0.5	NA	<0.5	<0.5	NA	<0.5	<0.5	NA	<0.5	<0.5	NA
Silver	<0.12	<0.12	NA	<0.12	<0.12	NA	<0.12	<0.12	NA	<0.12	<0.12	NA	<0.12	<0.12	NA
Zinc	41	33	NA	35	36	NA	51	35	NA	55	33	NA	35	39	NA
PCBs															
Aroclor 1254	<0.0088	NA	<1	<0.012	NA	<1	<0.021	NA	<1	<0.016	NA	<1	<0.018	NA	<1
Aroclor 1260	<0.0088	NA	<1	<0.012	NA	<1	<0.021	NA	<1	<0.016	NA	<1	<0.018	NA	<1
Organochlorines															
Aldrin	<0.088	NA	<10	<0.12	NA	<10	<0.21	NA	<10	<0.16	NA	<10	<0.18	NA	<10
a-BHC	<0.088	NA	<10	<0.12	NA	<10	<0.21	NA	<10	<0.16	NA	<10	<0.18	NA	<10
b-BHC	<0.088	NA	<10	<0.12	NA	<10	<0.21	NA	<10	<0.16	NA	<10	<0.18	NA	<10
d-BHC	<0.088	NA	<10	<0.12	NA	<10	<0.21	NA	<10	<0.16	NA	<10	<0.18	NA	<10
g-BHC	<0.088	NA	<10	<0.12	NA	<10	<0.21	NA	<10	<0.16	NA	<10	<0.18	NA	<10
4,4-DDD	<0.088	NA	<10	<0.12	NA	<10	<0.21	NA	<10	<0.16	NA	<10	<0.18	NA	<10
4,4-DDE	<0.088	NA	<10	<0.12	NA	<10	<0.21	NA	<10	<0.16	NA	<10	<0.18	NA	<10
4,4-DDT	<0.088	NA	<10	<0.12	NA	<10	<0.21	NA	<10	<0.16	NA	<10	<0.18	NA	<10
Dieldrin	<0.088	NA	<10	<0.12	NA	<10	<0.21	NA	<10	<0.16	NA	<10	<0.18	NA	<10
Endosulfan	<0.088	NA	<10	<0.12	NA	<10	<0.21	NA	<10	<0.16	NA	<10	<0.18	NA	<10
Endrin	<0.088	NA	<10	<0.12	NA	<10	<0.21	NA	<10	<0.16	NA	<10	<0.18	NA	<10
Heptachlor	<0.088	NA	<10	<0.12	NA	<10	<0.21	NA	<10	<0.16	NA	<10	<0.18	NA	<10
Heptachlor epoxide	<0.088	NA	<10	<0.12	NA	<10	<0.21	NA	<10	<0.16	NA	<10	<0.18	NA	<10
Methoxychlor	<0.176	NA	<20	<0.24	NA	<20	<0.42	NA	<20	<0.32	NA	<20	<0.36	NA	<20
Lipid (%)	0.88			1.2			2.1			1.6			1.8		
Collection Date	9/30/94			9/30/94			9/30/94			10/26/94			10/26/94		

Table 2					
Maximum allowable (or proposed maximum) contaminant concentrations					
in animal products (mg/kg wet wt.)					
		Tissue			
Chemical	Location	Liver	Meat		Reference
Cadmium	USA	1.5			Stansley et al. 1991
	USA		0.1 (diet)		Eisler 1985
	Slovenia	0.5			Doganoc & Gacnik 1995
	Poland		0.05		Swierqosz et al. 1993
	Finland	0.5	0.05		Niemi et al. 1995
Copper	Poland		8		Swierqosz et al. 1993
Lead	Poland	0.5			Swierqosz et al. 1993
	?	0.8	0.3		Eisler 1988
	Finland	0.5	0.05		Niemi et al. 1995
Zinc	Australia		40(seafood)		Eisler 1993
PCBs	USA		2 (fish)		FDA
DDTr	USA		5		FDA
Aldrin	USA		0.3		FDA
Dieldrin	USA		0.3		FDA